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ABSTRACT

This training manual is designed to introduce and assist naval personnel in the conversion from the English system of measurement to the metric system of measurement. The book tells what the "move to metrics" is all about, and details why the change to the metric system is necessary. Individual chapters are devoted to how the metric system will affect the average person, how the five basic units of the system work, and additional information on technical applications of metric measurement. The publication also contains conversion tables, a glossary of metric system terms, and guides to proper usage in spelling, punctuation, and pronunciation of the language of the metric system. (MP)

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THE METRIC SYSTEM

AMERICA MEASURES UP!

NAVAL EDUCATION AND TRAINING COMMAND

NAVEDTRA 475-01-00-79

PREFACE

This training manual is designed to introduce and assist naval personnel in the conversion from the English system of measurement to the metric system of measurement. The text and illustrations were prepared by DMCM Glen Anderson and JOC Paul Gallagher at the Naval Education and Training Program Development Center, Pensacola, Florida, for the Chief of Naval Education and Training.

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Although the words "he", "him", and "his", are used sparingly in this manual to enhance communication, they are not intended to be gender driven nor to affront or discriminate against anyone reading *The Metric System.*

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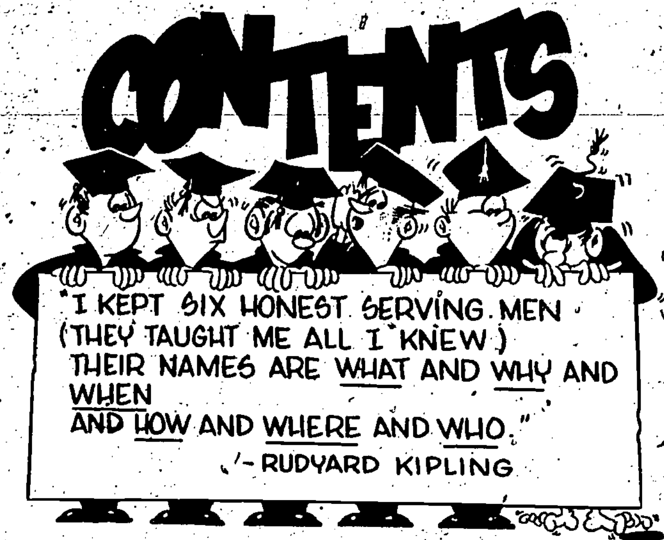
THE METRIC SYSTEM

America Measures Up

Prepared by,
DMCM Glen Anderson
and
JOC Paul Gallagher


CONTENTS
"I KEPT SIX HONEST SERVING MEN
(THEY TAUGHT ME ALL I KNEW)
THEIR NAMES ARE WHAT AND WHY AND WHEN
AND HOW AND WHERE AND WHO."
-RUDYARD KIPLING

INTRODUCTION

(A BRIEF METRIC PRELUDE)

TA-TA-DA-DUM! STRIKE UP THE BAND! SING ALONG WITH SAM - IF YOU DON'T KNOW THE WORDS - HUM! IT'S AN OLD, FAMILIAR TUNE AND WE'LL HELP YOU WITH THE SECOND VERSE! HOUSE LIGHTS - CURTAIN - HERE WE GO!

THE MOVE TO METRICS

Practically every nation in the world now uses a very simple and logical system of measurement called the metric system.

The United States has decided to use the metric system also. It is much simpler and easier to use than our older and more complicated English system of weights and measures.

The change from the English system to the metric system is already underway. It is planned to take place gradually, but perhaps you have already noticed some of the changes taking place around you.

The change to metrics is not difficult. We will still use the same mathematics (addition, subtraction, multiplication, and division) learned in grammar school. We are also very familiar with the decimal system which is the heart of the metric system.

In fact, we actually have very little learning to do at all, except why the change is necessary, what effect it will have on our lives and how these very simple metric units of measurement are to be used.

This book is designed to help you discover for yourself the necessity, simplicity, and personal benefits of learning and using the metric system to keep pace with the world in which we live.

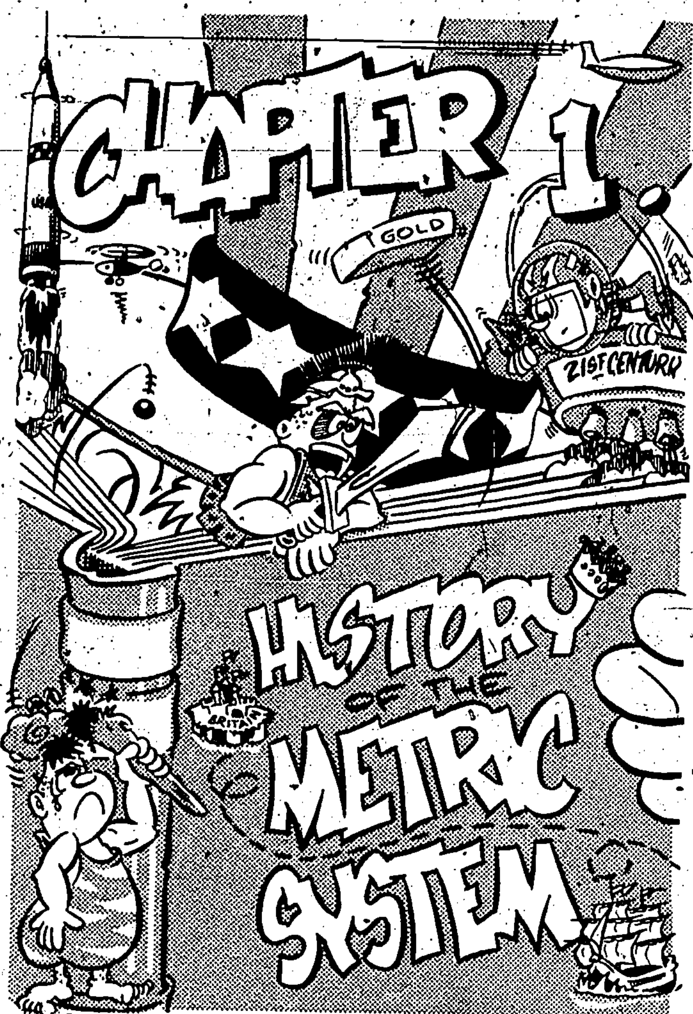
History of the Metric System

Is a change to the metric system necessary?

To understand how necessary and very important a change is, you must first understand some facts about both the old (English) and new (metric) systems.

This chapter will help you compare the two. You will see the change IS necessary—in fact, the sooner the better.

We think, after reading these chapters, you will agree that in giving up the old English system, nothing of value has been lost.



PASS THROUGH THE PORTALS OF TIME... SEE THE DAWN OF CIVILIZATION... UNRAVEL THE MYSTERIES OF THE METRIC UNIVERSE... ANSWER THE QUESTION - IS THIS TRIP NECESSARY?

HERE WE ARE AT "SQUARE ONE"–BEFORE THE DAWN OF CIVILIZATION WHEN THERE WERE NO STANDARDS OF MEASUREMENT. THIS CONDITION CAUSED MUCH CONFUSION AMONG PEOPLE IN TERMS OF COMMUNICATION AND TRADE.

The need for a unified system of weights and measures has existed since the beginning of time.

When there was no system, there was no means of communication in terms of weights and measures.

Trade was difficult, if not impossible. The world and its people suffered greatly under these conditions and did not progress or prosper for thousands of years.

EACH TIME A NEW CIVILIZATION WAS BORN--SO WAS A NEW SYSTEM OF MEASUREMENT. DOWN THROUGH THE AGES, THE EGYPTIANS, GREEKS, AND ROMANS (AMONG MANY OTHERS) ALL GOT INTO THE ACT.

When people began to group together, civilizations were formed, so there was an urgent need for a unified system of weights and measures.

These civilizations were far apart, and each developed its own separate system of weighing and measuring things.

What these separate systems did have in common was that none were scientific or accurate, as none were based on anything stable or unchanging.

For example, the Egyptians declared a cubit to be equal to the distance of the forearm. But forearms are very different in length.

The Greeks and Romans both had their own ideas of what a foot was. Again, they used no stable base for their calculations. They had philosophy and they had law, but lacked the scientific means to discover and base their measurements on anything that would remain constant.

QUITE OFTEN, THESE VARIOUS SYSTEMS OF MEASUREMENT WERE FORCED ON ONE CIVILIZATION BY ANOTHER THROUGH CONQUEST. THIS WAS EXACTLY THE CASE IN 55-54 B.C., WHEN THE ROMANS "INTRODUCED" THEIR SYSTEM TO SOME OF OUR ANCESTORS IN THE BRITISH ISLES.

The Romans, in particular, were a very aggressive and adventuresome civilization.

They set out to establish their Roman Empire in the Old World, and in so doing spread their ways of weights and measures throughout the nations they conquered.

The Romans conquered Great Britain in 54-55 B.C. and made the people "knuckle under" to Roman ways—including accepting the Roman system of weights and measures.

BRITISH ROYALTY SPENT 500 YEARS (12th - 16th CENTURIES) TRYING TO STRAIGHTEN OUT THE ENGLISH SYSTEM OF MEASUREMENT–THEIR ROYAL DECREES ONLY ADDED TO THE CONFUSION.

Once Britain became free to make its own decisions the question of a unified system of weights and measures arose again.

For 500 years various kings of England tried to standardize their system of measurement.

Being kings, they simply "ruled" what particular units of weight or measure were to be, and sent out the decree throughout the land.

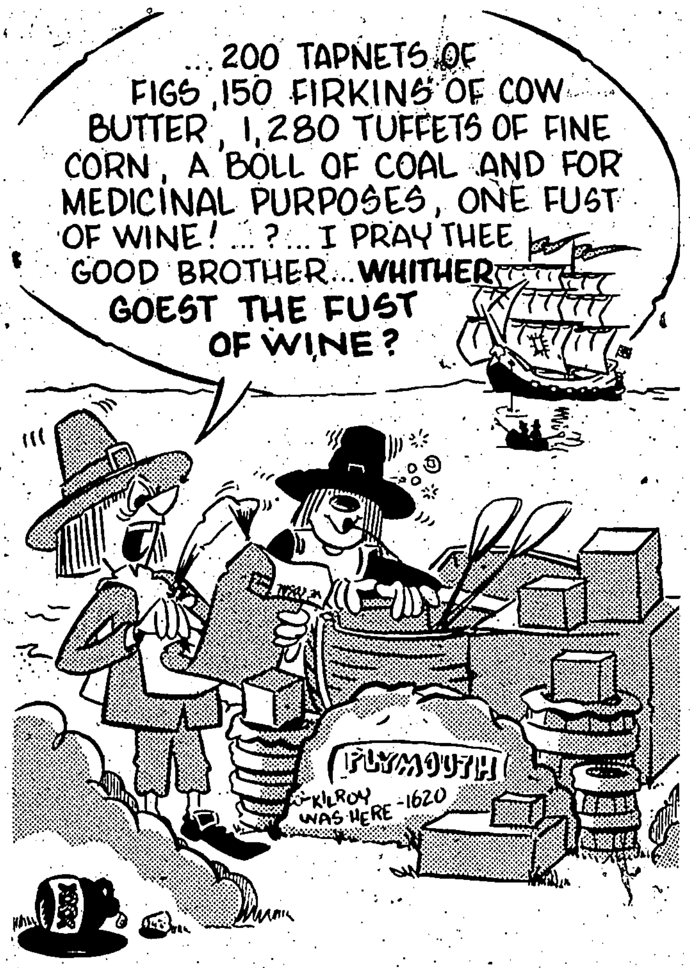
Here are some samples of those "standard" weights and measures:

- One yard = the distance from the king's nose to his thumb.

- One mile = (changed from 5,000 Roman paces) the distance of 8 furlongs (used in horseracing) or 5,280 feet.

- One hundredweight (changed from 100 to 112 pounds)—only King Edward knows why and we now have "short" (2,000 pounds) and "long" (2,240 pounds) tons as a result.

Again the only thing "uniform" about the English system was that it had constantly missed the mark of being based on anything stable or meaningful.



IT WAS EXACTLY THIS SAME CONFUSING FORM OF MEASUREMENT WHICH THE FIRST COLONISTS BROUGHT WITH THEM TO THE NEW WORLD. (WE SUSPECT THE QUARTERMASTER HAD A GOOD DEAL OF TROUBLE KEEPING TRACK OF EVERYTHING WITH SO MANY UNITS TO DEAL WITH!)

When the British colonized America, they brought their English system of weights and measures with them.

In addition to feet, yards, pounds, and tons, they had aums, binds, bings, bolls, bumkyns, butts, chaldrons, fatts, flykes, fothers, fusts, pipes, puncheons, shids, swods, tapnets, tuffets, wagas, and a waya or two.

Do any of these terms mean anything to you? Of course not! They must have meant even less to the colonists because the terms completely disappeared from the English system of measurement as we know it today.

That made the English system simple—or did it? We'll see!

AS THE COLONIES EXPANDED, SO DID THE NUMBER OF SYSTEMS OF MEASUREMENT. THE WEIGHT OR MEASURE OF TRADE GOODS OFTEN DEPENDED ON "WHAT SIDE OF THE LINE YOU WERE STANDING ON" WHEN THE DEAL WAS MADE.

ABOUT THIS SAME TIME, THE FIRST ATTEMPT WAS BEING MADE IN FRANCE TO DEVELOP A STANDARD SYSTEM OF MEASUREMENT FOR THAT COUNTRY.

The colonies in America grew. They were also far apart like the early civilizations, and did things differently.

For instance, each area developed its own idea of what the weight of a "bushel" was (Missouri 35 pounds; Kentucky, 33-1/2 pounds; New Jersey, 32 pounds; Connecticut, 28 pounds). This was only for a bushel of oats!

Today, a bushel depends on what's to be weighed—wheat, 60 pounds; barley, 48 pounds; oats, 32 pounds; rye and corn, 56 pounds each. That's not all—Webster's table of weights and measures still (359 years later) cautions "some states have specifications varying from these."

While the colonists were having difficulty agreeing with one another in America, Gabriel Mouton of France proposed a decimal system for his country in 1670.

The decimal was to become the "seed" from which the metric system was to grow, but for the time being Mouton's proposal was turned down by his country. It was left to history to recall his wisdom.

DURING THE 18TH CENTURY, THE UNITED STATES DECIDED TO USE THE DECIMAL FOR ITS MONETARY SYSTEM. FRANCE DECIDED TO USE THE DECIMAL FOR ITS RAPIDLY DEVELOPING METRIC SYSTEM. BRITAIN DECIDED TO REMAIN UNDECIDED, AND DID—FOR THE NEXT ONE-HUNDRED-SEVENTY YEARS.

America recognized how valuable the decimal system was in 1784 and approved it for use in our monetary system.

You still recognize the decimal today as 0.01, 0.05, 0.10, 0.25 and 0.50 when you count your pennies, nickels, dimes, quarters and half dollars—all a portion of the "whole" dollar ($1.00).

Mouton's decimal system had to wait out the 17th (and part of the 18th) century in limbo until 1790 when Charles Maurice Talleyrand of the French Assembly asked the French Academy of Sciences to establish a uniform system of weights and measures.

The Academy, in deciding upon a system of numbers by which to measure, selected the decimal because it was simple to multiply and divide by.

It took the Academy 5 years (1790-1795) to complete its work in developing the metric system. It took France itself until 1840 to accept it.

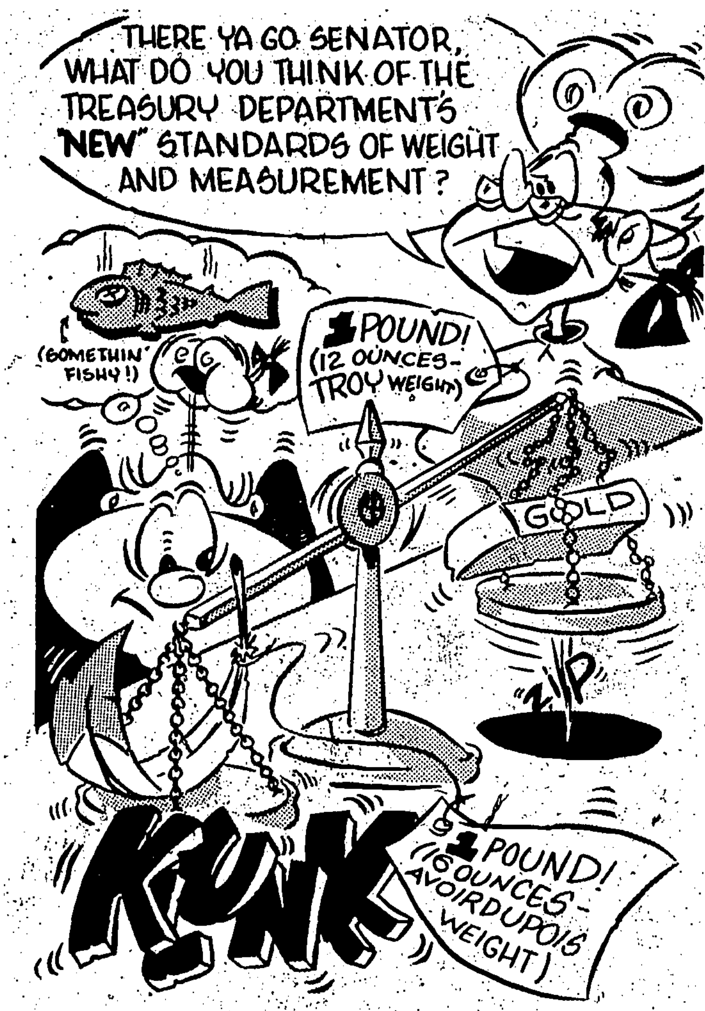
BY THE TURN OF THE 19TH CENTURY THE METRIC SYSTEM WAS BEING USED IN EUROPE. IT WAS ALSO HIGHLY FAVORED BY OUR LEADERS IN THE UNITED STATES. UNFORTUNATELY, WE WERE STILL TIED TIGHTLY TO BRITAIN IN MATTERS OF TRADE AND BRITAIN WAS TIGHTLY TIED TO ITS OLD WAYS.

The question arises—If America recognized the value of the decimal system itself in 1784, why didn't it logically follow that we accept the metric system when it became available 11 years later?

Prominent Americans such as Thomas Jefferson and later John Quincy Adams supported proposed changes from the complicated English system of measurement. Adams in particular favored the French metric system.

It looked as though the scene was set and the time ripe for a change, but the United States was at that time conducting most of its trade with Great Britain which was still using the (you guessed it) English system of weights and measures.

You know that when you trade with someone for something you desperately need, you trade on their terms. Pay close attention class, you'll hear this again later on!



IN 1830, THE U. S. TREASURY DEPARTMENT TRIED ONCE MORE TO STANDARDIZE THE OLD ENGLISH SYSTEM OF WEIGHTS AND MEASURES. CONGRESS THANKED THEM FOR THE EFFORT, BUT DID NOT ACCEPT THEIR "NEW" SYSTEM LEGALLY OR OFFICIALLY AS THE SYSTEM OF WEIGHTS AND MEASURES FOR THE UNITED STATES.

Meanwhile, back in the U. S.—in 1830 a Treasury Department employee, one Ferdinand Hassler, was primarily responsible for attempting to further "standardize" our English system of weights and measures.

Congress thanked Hassler for the system, but, nonetheless, refrained from accepting the system for legal or official use.

The Treasury Department, however, introduced Hassler's system to the various states of the Union, and it became the customary system of weights and measurements much as we know it today—complete with different kinds of pounds (troy and avoirdupois); tons (long, short); ounces (liquid and dry); bushels (remember them?)—not to mention an assortment of pecks, rods, poles, perches, furlongs, leagues, cords, links, chains, acres, sections, townships, fathoms, cables, statute/nautical miles, pints, quarts, gallons, barrels (Imperial and U.S.) minims, drums, grains, penny weights, carats, scruples, and maybe one or two others we have missed. Thanks, Ferdinand!

ALTHOUGH THE 19TH CENTURY HAD BROUGHT NOTHING BUT CONTINUED FAILURE AND FRUSTRATION IN ATTEMPTS TO STRAIGHTEN OUT THE OLD ENGLISH SYSTEM OF MEASUREMENT, THE METRIC SYSTEM, ON THE OTHER HAND, WAS STILL RAPIDLY GAINING POPULARITY AMONG MANY NATIONS–INCLUDING THE UNITED STATES.

It should, therefore, come as no surprise to you that in 1866 Congress legalized the metric system for trade in the United States.

In 1875 the United States participated in a conference of nations which met in Paris, France, and signed the Metric Convention that established an International Bureau of Weights and Measures headquartered in Paris.

The Bureau created prototypes for the basic units of length and weight. The United States received its copies and thereafter our yard was not 36 inches as custom would have it, but legally 0.91440183 meters; and our pound, not 16 ounces (customarily), but 0.4537924277 kilograms. How about that?

Which brings up the question—if this was so—why didn't the Government make it so a long time ago and save us the agony of the change?

As it turned out we can safely say our Government did the right thing by "not rushing into anything." The prototypes mentioned were created from platinum. Platinum was not a good selection because it was subject to damage each time it was handled.

The same problem of having a truly stable base for weights and measures was still with us.

DURING THE FIRST THREE-QUARTERS OF THE 20TH CENTURY, THE METRIC SYSTEM BECAME "FINALIZED" AND WAS ACCEPTED BY 90% OF THE WORLD'S NATIONS AS THE INTERNATIONAL STANDARD FOR WEIGHTS AND MEASURES. IT SEEMED AS THOUGH "EVERYBODY HAD GONE METRIC." THERE WAS HOWEVER, ONE NOTABLE AND SURPRISING EXCEPTION. THE WORLD WAITED AND WONDERED.

It took until 1960 for the Bureau to find a stable natural standard—a wavelength of light on which to stabilize the meter. Science had at long last provided what century after century of mankind had sought in vain.

When the Bureau met in 1960 it adopted not only the stable basis for the meter but other metric units; the ampere, candela, and kelvin for measuring electrical current, light, and temperature.

The Bureau also "codified" the metric system into an international system of weights and measures which was called Le Système International d'Unités, or SI for short.

This is exactly what the world had been waiting for—a united international system of weights and measures. Those who had not already adopted the metric system were quick to do so. Britain adopted it in 1965, followed by our neighbor, Canada, in 1970. Where was America? Was the hand that guides the ship of state asleep at the helm?

IT DIDN'T TAKE LONG TO FEEL THE IMPACT THAT THE METRIC SYSTEM WAS HAVING ON THE MARKET PLACE OF THE WORLD. IN 1971, THE UNITED STATES SECRETARY OF COMMERCE RECOMMENDED THAT CONGRESS ADOPT A NATIONAL PROGRAM TO CHANGE THE U.S. OVER TO THE METRIC SYSTEM.

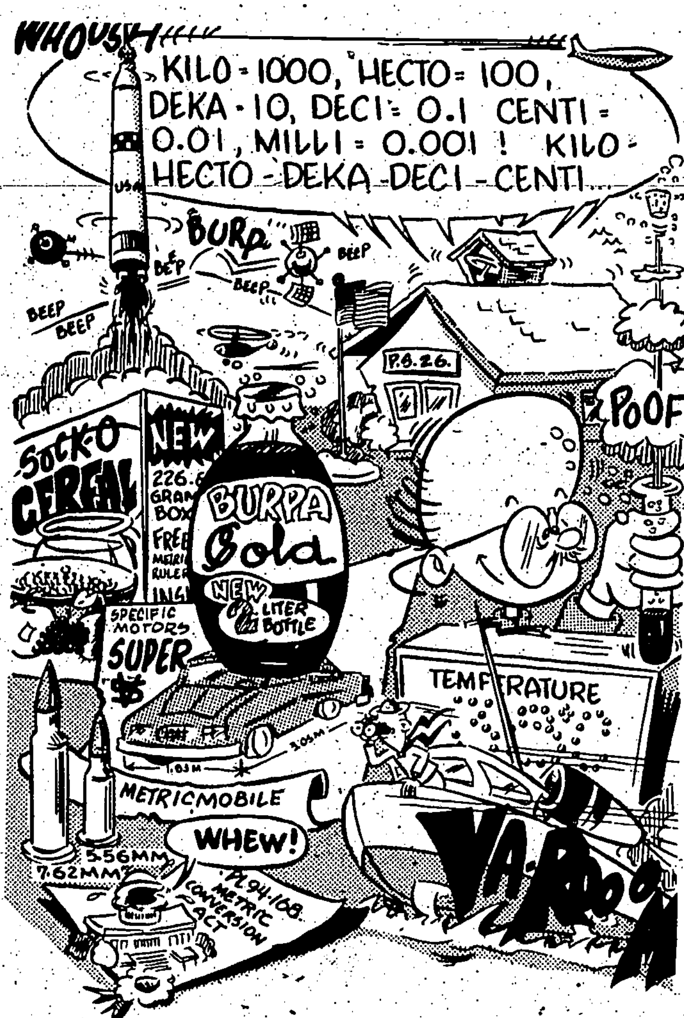
The United States began to add to an already heavy burden with its "tardiness" in getting started toward the metric system.

We were buying far more foreign goods than ever and selling less of our own goods to other nations.

We know what that means. The dollar was "leaving home," and when that happens it's hard times for everyone.

The United States and its people desperately need certain raw materials and products from other nations. Remember what was said about a person "in need" buying on the other person's terms?

By 1971, the Secretary of Commerce hollered "uncle" and asked Congress to get us started down the road toward adopting the metric system.



IN 1975 CONGRESS PASSED THE METRIC CONVERSION ACT, WHICH WAS SIGNED INTO PUBLIC LAW 94-168 BY PRESIDENT FORD. THE MOVE TOWARD BECOMING A METRIC NATION WAS UNDERWAY.

In 1975 Congress passed the Metric Conversion Act, which was signed into Public Law (94-168) by President Ford.

By that time, the only remaining nonmetric countries were Liberia, Burma, the Yemen Arab Republic, and the tiny country of Brunei.

"Meanwhile, back in the States," our conversion to metrics is in full swing.

Our younger generation is being taught the metric system in public schools.

Science, business, and industry are developing more and more metric products for foreign and domestic trade.

The completion of our country's changeover to the metric system "looms just over the horizon."

THE TIME TO LEARN ABOUT THE METRIC SYSTEM IS NOW—WHILE THERE IS TIME. THE ALTERNATIVE IS TO LAND RIGHT BACK TO "SQUARE ONE" WITH NO MEANINGFUL WAY TO COMMUNICATE OR TRADE IN TERMS OF WEIGHTS AND MEASUREMENTS.

The Metric Conversion Act provides for a gradual changeover to the metric system.

Historically, the change to metrics has met with resistance, as does any change, but in the end the change has always been completed.

So, it is important that you realize that the time to learn about metrics is NOW, during the period allotted for the changeover. As we move toward the 21st century, the alternative is to land ourselves "back to square one."

In the beginning we said we thought you would agree to two things:

(1) that the change to metrics is necessary;

(2) that we won't miss the English system when it's gone.

You should easily see the effect that having or not having the metric system has on our economy, and the urgency now is for change.

You should have no guilt about trading off the 80 (that's right, 80) different standards of the archaic English system of measurement for the five basic units of the metric system in terms of length, weight (mass), volume, temperature, and time.

These are the meter, gram, liter, degree (Celsius), and second.

Now then—do we hear any objection? We thought not. Acceptance of the metric system is just plain old common sense, a quality which Americans have set great store in for generations.

Fine! The switch to metrics IS necessary. It's been left up to OUR generation to see that metrics is a practical idea whose time has come and accept that fact. We can even do without the English system, which even the English Government has abandoned for the metric system.

Now that America has decided to dump the English system of measurement, how do we know we can live with metrics?

Simple! Because that's exactly what we have been doing for a very, very, long time.

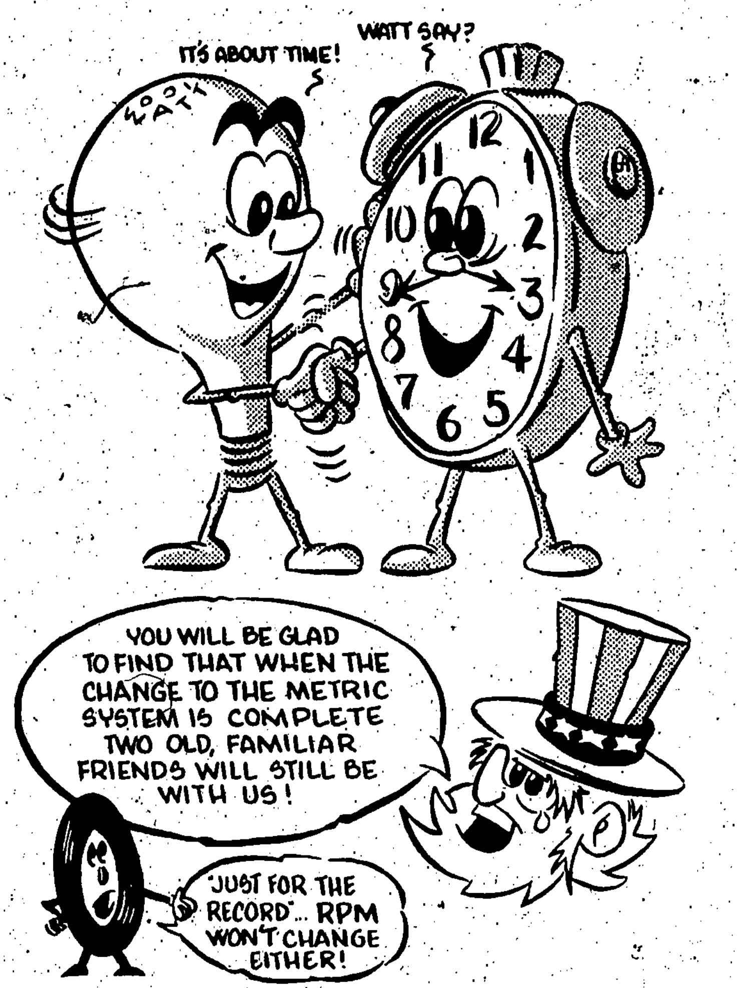
DOES THE THOUGHT OF "LIVING WITH METRICS" SEND CHILLS UP AND DOWN YOUR SPINE? WILL THEY (HEH-HEH) "CHANGE YOUR LIFE"? **DARE YOU** CROSS THE THRESHOLD TO THE UNKNOWN? COME - LET US "TAKE YOU TO OUR LITER!"

WE ACTUALLY KNOW MORE THAN WE THINK ABOUT METRICS. THE THINGS PICTURED ARE ONLY A FEW METRIC PRODUCTS WHICH HAVE BECOME A PART OF OUR LIVES. OUR LIVES HAVE BEEN MADE BETTER BECAUSE OF THESE THINGS.

The metric system is no stranger to the people of the United States. Practically everyone of us has purchased or used something "metric" in our lives. The illustrations on the left are just a few of the more familiar metric items which are a routine part of our daily lives.

The question is—can you really tell whether other items which surround you are metric or English? Look again, you may be mildly surprised.

Science, medicine, business, and industry have provided us with many beneficial products all of which we have used without question and many of which conform to the metric system.



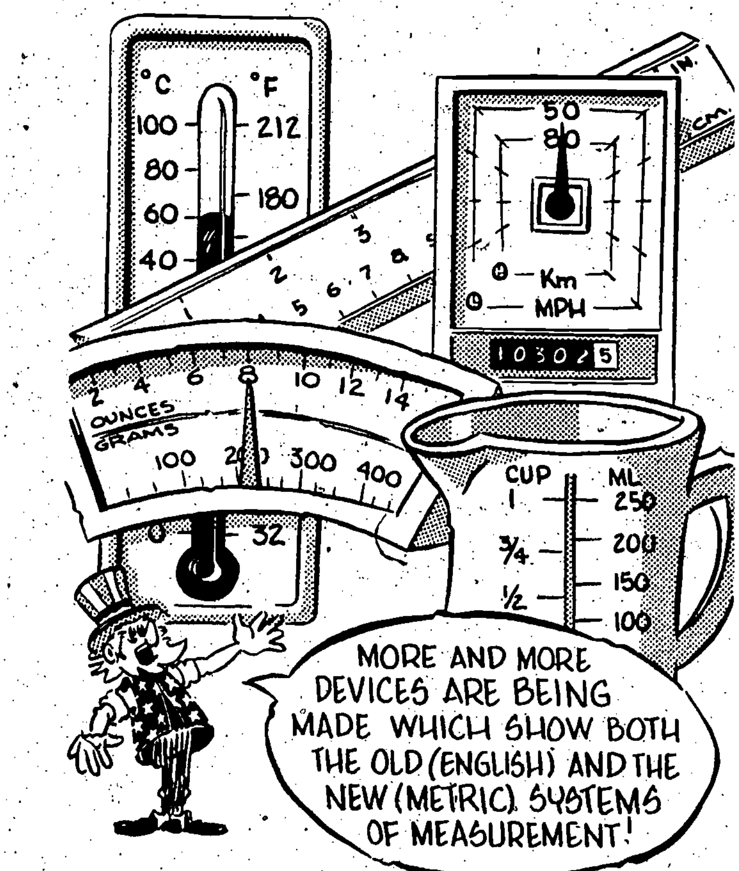
THE FACT THAT WE ARE CHANGING TO THE METRIC SYSTEM OF MEASUREMENT DOES NOT MEAN THAT EVERYTHING WITH WHICH YOU ARE FAMILIAR WILL CHANGE.

Ready for more surprises? You already know some things about metrics!

TIME, one of the five basic metric units will not change. Neither will the WATT, which is the SI unit for power of any kind. RPM (revolutions per minute) will also remain the same.

How about that? We've barely started learning about metrics and you already know 20 percent of the basic metric units by heart.

That leaves length, weight, volume, and temperature to learn. Let's see what's being done in those departments.



THE CHANGES WHICH ARE BEING MADE FROM THE OLD TO THE NEW SYSTEM OF MEASUREMENT ARE ALSO BEING MADE VERY EASY FOR US TO UNDERSTAND.

Just as we thought! Somebody beat us to the patent office again—this time with dually calibrated instruments which show both forms of measurement. There they are—length, weight, volume, and temperature—the remaining four basic metric units.

Let's consider the automobile speedometer for the moment. Suppose you're cruising down an interstate and you come upon a speed sign that indicates the speed limit is 80 km (the equivalent of 50 mph). Panic Time? No such thing, you simply "take the pedal off the metal" and back down the metric scale till you reach 80 km, the legal metric speed limit.

This same simplicity applies to each of the other basic metric units and devices.

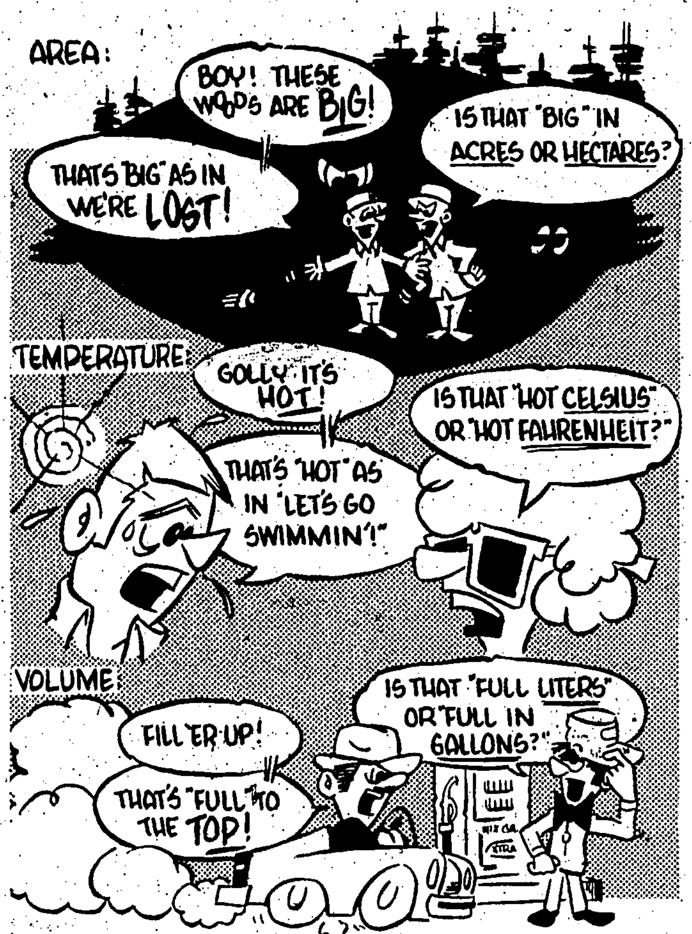
"ACCEPTING THE CHANGE TO THE METRIC SYSTEM IS ALSO A MATTER OF REALIZING THAT IT DOES NOT MEAN THERE WILL BE A SUDDEN CHANGE IN OUR DAILY LIVES..."

DISTANCE AND TIME

MASS

Therefore, if you have been expecting some sort of a crisis in your life because of the change to metrics you are going to be disappointed.

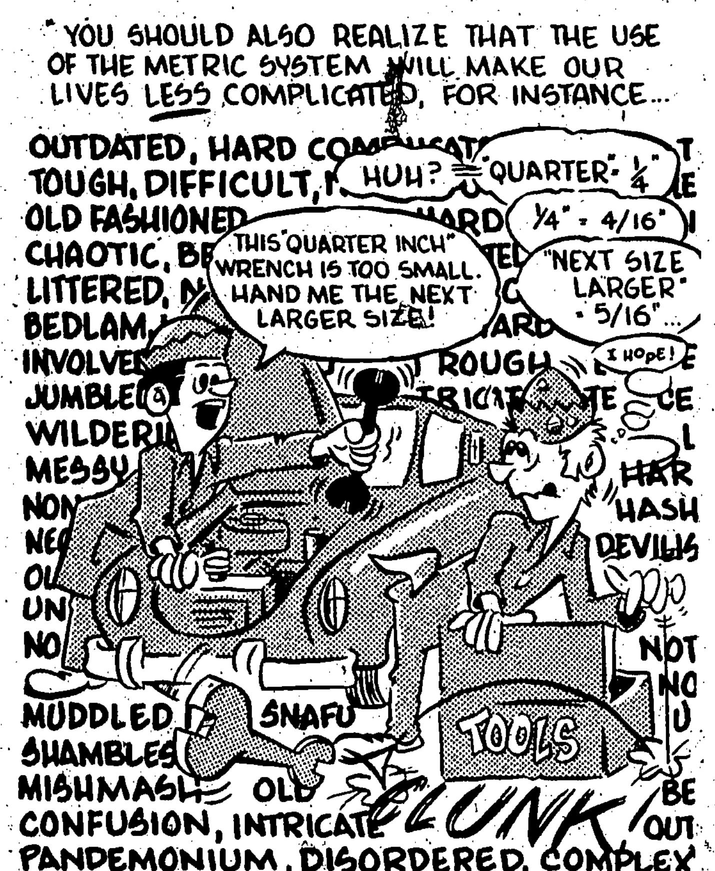
In fact, on many occasions the change to metrics won't affect us one bit. Consider the pictures on the opposite page and the page that follows.



MANY TIMES THE FACTS ABOUT THINGS ARE OF FAR MORE IMPORTANCE TO US THAN THE FIGURES, OR UNIT OF MEASUREMENT WHICH WE ASSOCIATE WITH THOSE FACTS.

Now then, would we lie to you? Of course not! Ask yourself, when was the last time you weighed a pill bottle, got "turned around" in precisely 1,237½ acres of dense forest, went swimming in water that was exactly 82 degrees Fahrenheit, or actually put 20 gallons of gas, to the last drop, into a 20-gallon tank?

With metrics it's the same—no different. If there is any difference, it is in the simplicity of the metric system.



USING THE ENGLISH SYSTEM OF MEASUREMENT, THE MECHANIC'S ASSISTANT HAS ONE OF THREE CHOICES:

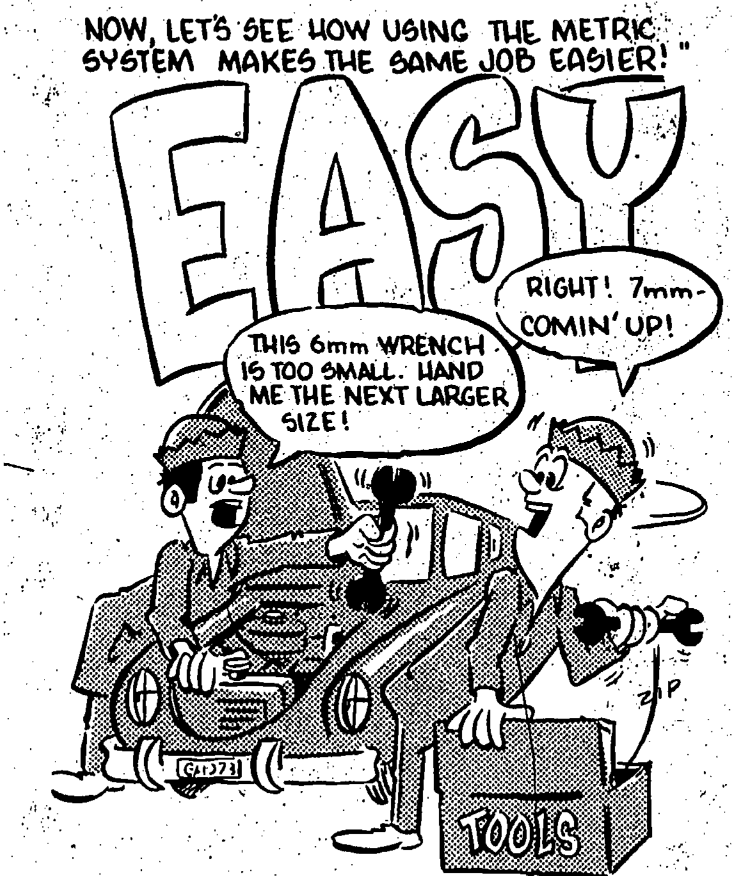
(1) COMPARE THE WRENCHES SIDE BY SIDE TO FIND THE NEXT LARGER SIZE

(2) DO SOME "MENTAL MATHEMATICS," CONVERTING SIXTEENTHS, EIGHTHS, QUARTERS, AND HALVES TO A COMMON DENOMINATOR TO FIND THE NEXT LARGER SIZE

(3) COMMIT ALL OF THE VARIOUS SIZES OF WRENCHES TO MEMORY IN THEIR PROPER ORDER TO KNOW WHICH IS LARGER OR SMALLER THAN THE OTHERS.

Recognize the predicament these people are in? Sure you do, we've all been there—if not in this particular state of confusion, then in one similar to it. Trying to deal with one or more of the 80 plus units of measurement in the English system is confusing.

The unfortunate mechanics in the illustration start out with "quarters" and end up with "sixteenths." Truthfully now, does that "compute"? Bet your combat booties it doesn't!



USING THE METRIC SYSTEM OF MEASUREMENT, THE MECHANIC'S ASSISTANT HAS ONLY ONE THING TO REMEMBER:

"THE LARGER THE NUMBER (IN MM)–THE LARGER THE WRENCH!"

SIMPLE? YOU BET!

That's the nice part about the metric system. You always come back from the store with what you went after. If you start with meters you end up with meters. They may be kilo-, hecto-, deka-, deci-, centi-, or millimeters, but they are still meters. That goes for grams, liters, degrees (Celsius), and the rest as well.

THE TRUTH IS THAT WE COULD MANAGE JUST AS WELL AND IN MOST INSTANCES BETTER, IF EVERYTHING WE KNEW ABOUT OR USED WITH THE OLD ENGLISH SYSTEM WERE TO DISAPPEAR AND BE INSTANTLY REPLACED BY THE SIMPLER METRIC SYSTEM.

Therefore, you can see for yourself that living with metrics is to your advantage.

In fact, it's easier than living with the English system, which we have already decided we could live without.

Now aren't you glad you took that last step across the metric threshold? Feel a little foolish about all the fuss you may have made over changing to metrics?

Don't! There's not one of us who hasn't been hesitant about accepting something that really "doesn't hurt a bit" without being a little apprehensive. Don't believe us? Check your inoculation record. How long has it been since you had your last flu shot anyway?

O.K. "metric fans," it's time to get down to business, so pay close attention.

Metrics is magic. For instance, you can take this one "itty-bitty, little-ole decimal what-cha-ma-call-it" and make it pop up most anywhere you want it to.

But we're getting ahead of ourselves. Come on inside, make yourself comfortable, and we'll show you our whole "bag of tricks."

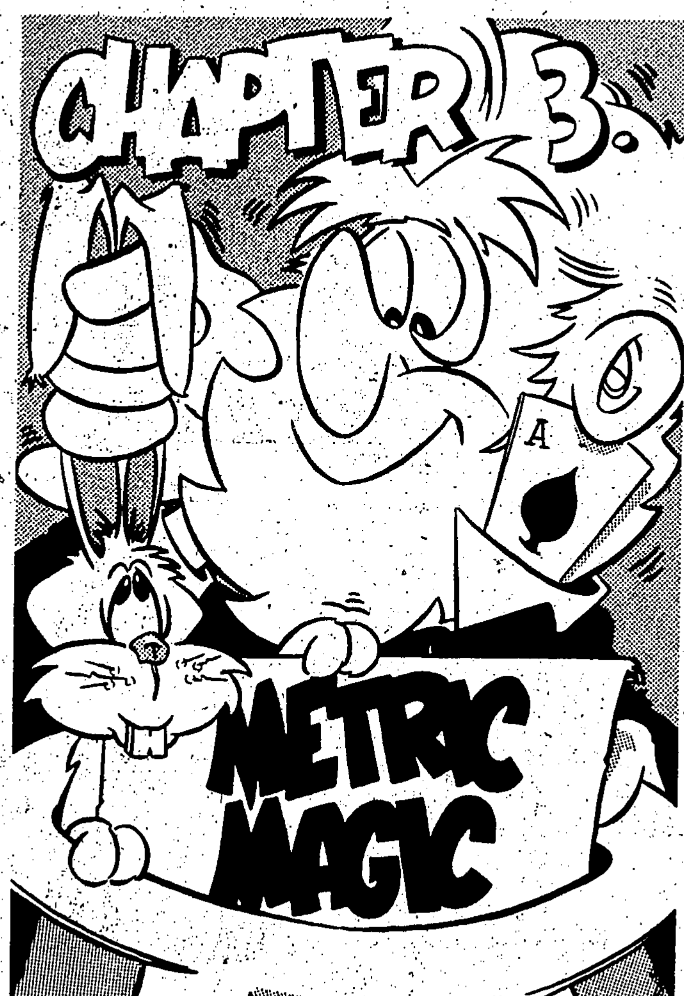
English system? Leave that outside, we don't want it tracking up our new magic carpet.

All the chapters and sections in this book are important, but this next chapter is probably the most essential in understanding the metric system. You will learn how to use metrics.

Fortunately, in our monetary system, all units of measurement are multiples of 100 or fractions thereof. Calculations require only the addition of zeros or moving the decimal point to the left or right, eliminating complicated fractions and making financial problem solving easier to teach and learn.

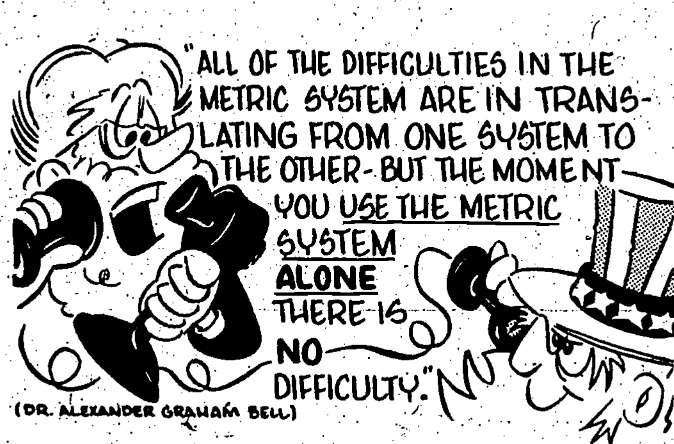
Why aren't all measurements of length, capacity, and weight based on a decimal system? Actually, over 90 percent of the world's people already use such a system, called the metric system. Based on the meter, a unit of measurement is universally defined as the wavelength of orange-red light emitted by a krypton-86 atom. You will now learn the official system of measurement in the United States.

And it's about time we learned to use this method. Yes, it will take time to "unlearn" our present organization of weights and measures, but getting the hang of the method will be simple enough. "It's always been that way" is no longer an acceptable excuse for our failure to master new and more efficient methods of calculation. Good luck with "metric magic"!



SEE THE **DANCING DECIMAL**! BEHOLD, AS THE **MAGIC** OF **METRICS** UNFOLDS BEFORE YOUR EYES! **AMAZE** YOUR FRIENDS WITH THE **ASTOUNDING POWER** OF **TEN** - IN JUST

ONE EASY LESSON



Now we will start learning the metric system. You will never forget the English system, but try to push inches, feet, yards, miles, and other English measurements out of the way for the moment. You don't need the old way to learn the new way. When you get used to it, you will see that the metric system is both quick and easy.

THE POWER OF TEN IS THE KEY

In the metric system each unit of measurement has its own name. Each unit is 10 times more than the next smaller unit.

MORE THAN ONE METER

A DECAMETER is 10 meters.
A HECTOMETER is 100 meters.
A KILOMETER is 1000 meters.

LESS THAN ONE METER

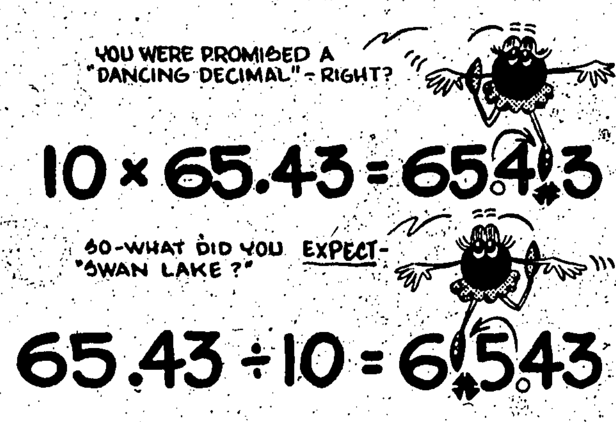
A DECIMETER is 1/10 of a meter. It takes 10 decimeters to make a meter.

A CENTIMETER is 1/100 of a meter. It takes 100 centimeters to make a meter.

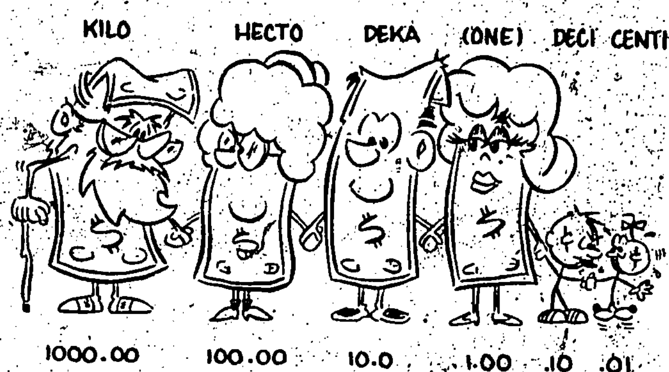
A MILLIMETER is 1/1000 of a meter. It takes 1000 millimeters to make a meter.

THE POWER OF TEN HOLDS THE "KEY" TO THE METRIC SYSTEM.

The great advantage to metrics is that it's a decimal system. Instead of having to convert measurements from inches to feet and feet to yards, all you have to do with metrics is multiply or divide by a factor of 10 to convert from one unit to another. If you have worked with decimal points, you know that involves moving a decimal point to the right or left. For example:

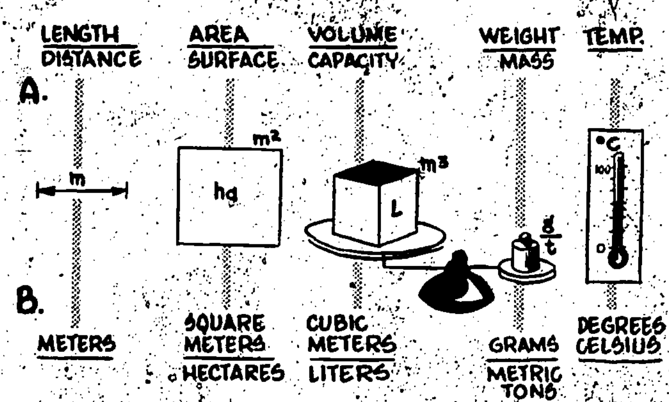


Just think about how our money system works, with the ten dollar bill, dimes, and cents all RELATED to the basic unit—the dollar.



AS YOU BEGIN TO WORK WITH METRICS, KEEP THE RELATIONSHIP BETWEEN THE DECIMAL SYSTEM, OUR MONETARY SYSTEM, AND THE NUMBER 10 IN MIND.

You must remember, when working with metrics, all units are related by the number 10. The ratio between the units of the series (dollars, dimes, cents) is ten. Additions, subtractions, and other numerical operations are simple. Figuring problems with metric units needs no conversion from unit to unit, which is necessary between inches and feet or ounces and pounds.

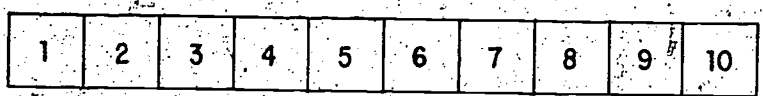


A. WHAT WE MEASURE
B. THE METRIC UNIT(S) WE MEASURE WITH

In the metric system there is only one series of units for length, one for area, one for capacity, one for mass, and one for temperature.

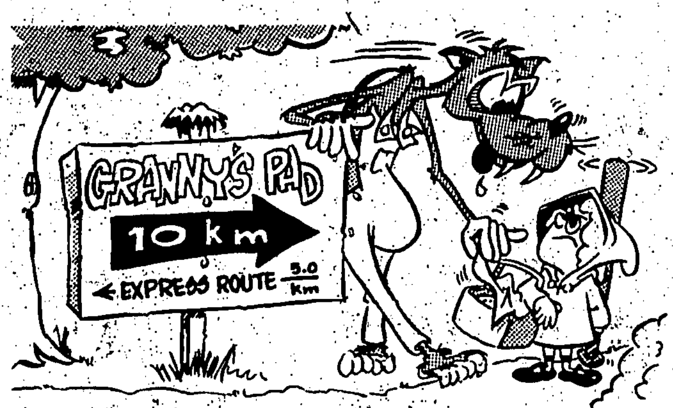
LENGTH

A meter is used to measure length. You can measure how long something is by using a meter stick. You can make a meter stick by measuring a thin piece of wood or a stiff piece of cardboard 10 times longer than this line.



The line is divided in centimeters. The distance between each mark is a centimeter long. Ten centimeters is called a decimeter. So, 10 decimeters (100 centimeters) is called a meter, the length of your meter stick.

The line above is a line that is 1 centimeter long. If you divide a centimeter into 10 equal parts, each mark is 1 millimeter from the next. You probably won't have to measure in millimeters often, but you should remember that there are 1000 of them in a meter.



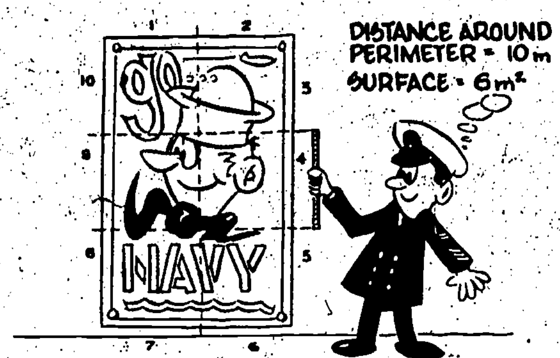
SOME ROAD SIGNS NOW TELL US THE DISTANCE BETWEEN PLACES IN KILOMETERS.

Now that you know how long a meter is, you can measure how long, how wide, and how high something is.

In the metric way of measuring distances, such as how far Norfolk is from San Diego, you would use kilometers. Some road signs in the U.S. now tell you how many kilometers it is from one place to another.

64

Try using metrics with your meter stick. Measure how tall you are or how wide a room is. The more you work with metrics the easier the system will be to understand.



MEASURING A PERIMETER IN METERS AND A SURFACE IN SQUARE METERS.

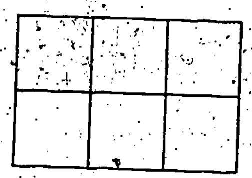
The Navy chief in this picture has measured a recruiting poster and discovered that it is 3 meters long and 2 meters wide. He wants to find out the perimeter of the canvas. Two sides measure 3 meters and two sides measure 2 meters each. So the chief would say its perimeter, which means the distance around the edges of anything, is . . .

$$\begin{array}{rr} & 3 \text{ meters} \\ & + \\ & 3 \text{ meters} \\ & + \\ & 2 \text{ meters} \\ & + \\ & \underline{2 \text{ meters}} \\ \text{Equals} & 10 \text{ meters} \end{array}$$

Now measure the perimeter of your bunk. It is the distance all the way around the four sides.

You now understand what the perimeter of a surface is. Now let's find how to measure the whole surface. . .not just the outside edges.

The chief's recruiting poster was 3 meters long and 2 meters wide and had a perimeter of 10 meters, but there is more to a recruiting poster than its outside edges. The entire surface of any object is its area.



The drawing above is 3 centimeters long and 2 centimeters wide. To discover the area the drawing covers, you would multiply the length by the width. Three centimeters times 2 centimeters equals 6 square centimeters. So, the surface area the drawing covers is 6 square centimeters. Surfaces can be measured in square centimeters, decimeters, meters, or kilometers. Just multiply the length by the width. The answer you get is the area of the surface.

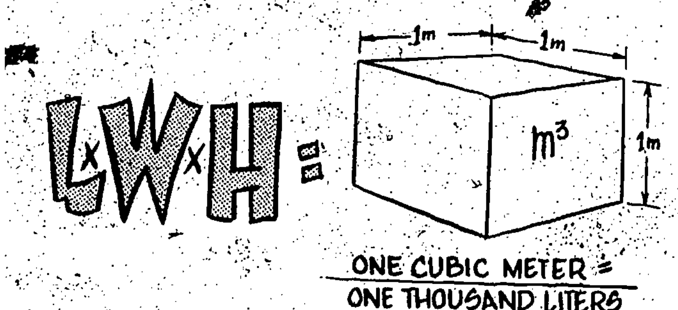
How would you measure the quantity of something? Finding out how much of anything is in a can, a bottle, or a box is easy because the metric system uses measurements that are like those you have already learned about.

You know a square meter would look like this in written form:

1 meter long
x
1 meter wide
Equals 1 square meter

Suppose you have a box with sides that measure 1 square meter each. An object with 6 equal square sides is called a cube. To discover how much a cube-shaped box will hold, multiply the height times the width times the length. For example:

1 meter
x
1 meter
x
1 meter
Equals 1 cubic meter



VOLUME AND CAPACITY MEASURED IN CUBIC METERS AND LITERS.

A LITER EXPRESSED AS CUBIC CENTIMETERS.

A cubic meter is too large to be a useful unit of measurement for most of the liquids you will want to know about. For example, if you poured a glass of beer into a box that would hold a cubic meter, it would barely cover the bottom.

So, the inventors of the metric system came up with a measurement called the liter. It is the common unit of measurement for liquids. There are 1000 liters in a cubic meter. In other words, a cubic meter is 1000 times bigger than a liter. It makes much more sense to use the liter to measure most liquids.

The picture above shows how big a liter box would be.

Each side measures 10 centimeters.

10 centimeters
x
10 centimeters
x
10 centimeters
Equals 1000 cubic centimeters

A box that is 1000 cubic centimeters will hold 1 liter.

Use the same prefixes that we learned with the meter to show that each unit is 10 times more than the next smaller unit.

MORE THAN ONE LITER

A DECALITER is 10 liters.

A HECTOLITER is 100 liters.

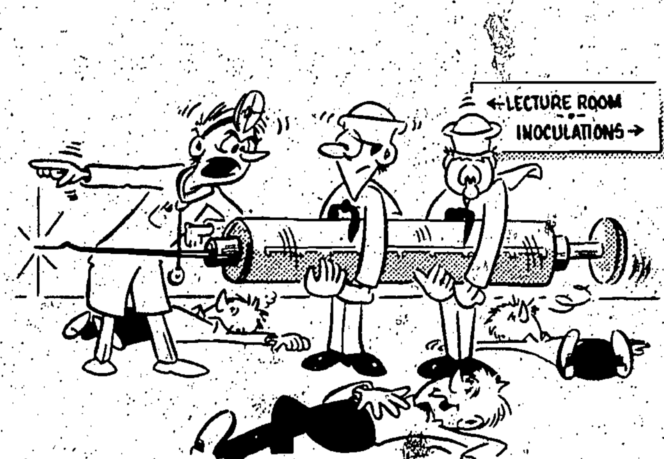
A KILOLITER is 1000 liters.

LESS THAN ONE LITER

A DECILITER is 1/10 of a liter. It takes 10 deciliters to make a liter.

A CENTILITER is 1/100 of a liter. It takes 100 centiliters to make a liter.

A MILLILITER is 1/1000 of a liter. It takes 1000 milliliters to make a liter.

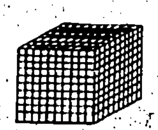


"GET THAT TRAINING DEVICE ON DOWN TO THE LECTURE ROOM. YOU'RE SCARIN' HELL OUTA MY PATIENTS!"

Many stores now have liter measures for sale. The next time you visit sickbay, you might ask to see the syringe the corpsman gives injections with. You will see that the tube is marked to tell how much of a liter it holds.

If you filled the liter box shown on page 66 with pure water that is not too hot or too cold, the water would weigh just about 1 kilogram. The gram is the unit of measurement most often used for weight in the metric system. Since the kilogram is 1000 grams and a liter is 1000 cubic centimeters, we know that 1 gram of water is equal to 1 cubic centimeter of water. We call this amount of liquid a milliliter.

This box measures 1 cubic centimeter. See how small it is. When we want to measure only a small amount of liquid, we measure in cubic centimeters.



How much does it weigh? Weight in the metric system is usually expressed in grams. Use the same prefixes that we learned with the meter and the liter to show that each unit is 10 times more than the next smaller unit.

MORE THAN ONE GRAM

A <u>DECAGRAM</u> is 10 grams.

A <u>HECTOGRAM</u> is 100 grams.

A <u>KILOGRAM</u> is 1000 grams.

LESS THAN ONE GRAM

A <u>DECIGRAM</u> is 1/10 of a gram. It takes 10 decigrams to make a gram.

A <u>CENTIGRAM</u> is 1/100 of a gram. It takes 100 centigrams to make a gram.

A <u>MILLIGRAM</u> is 1/1000 of a gram. It takes 1000 milligrams to make a gram.

WEIGHT EXPRESSED IN GRAMS. THESE 100 mg TABLETS ARE 1/10 OF A GRAM IN WEIGHT. (1g = 1,000 mg, 100 mg = 1/10 of 1,000 mg). THE POWER OF TEN APPLIES.

To measure the metric weight of an object you have to use a scale that gives weight in grams. But, if you don't have a metric scale handy you can get an idea of how much the units represent by looking at the labels of some products that are sold in stores by metric weight. For example, vitamin tablets are labeled according to how much of a particular vitamin they contain. Vitamin C, for instance, can be bought in 100, 250, or 500 milligram amounts.

At birth a baby would normally weigh from 2 to 4 kilograms. A baby elephant can weigh as much as 100 kilograms at birth and grow up to weigh more than 2 metric tons! The metric ton is 1 million (1,000,000) grams.

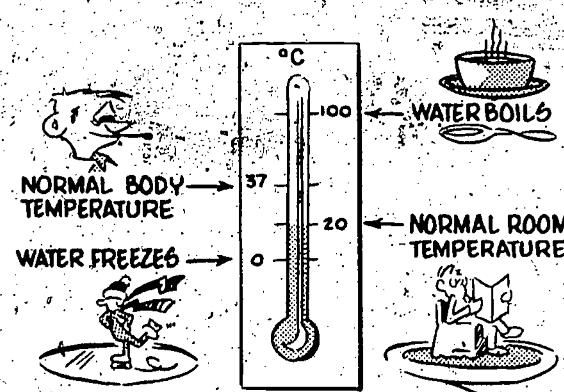
In the near future, most of the things you will buy by weight at the grocery store will be sold in kilograms. Twelve apples will probably weigh about 2 kilograms. Most people buy about 2.5 kilograms of flour or sugar at a time.

HOW HOT OR COLD IS IT?

There is a metric measurement for temperature you will want to know about. We measure heat by degrees on a thermometer. There are three kinds of thermometers in use today: Kelvin (used by scientists), Fahrenheit (the one you are most familiar with), and the Celsius thermometer, which is used in most metric system countries.

We are now making the change to the Celsius thermometer. A man named Anders Celsius, who lived more than 200 years ago, thought of marking a thermometer in centigrades. He marked the freezing point of water at 0 degrees and the boiling point at 100 degrees.

Weather reports on radio and TV now give the temperature in degrees Celsius, as well as in degrees Fahrenheit.



MEASURING TEMPERATURE IN DEGREES CELSIUS.

THE TEMPERATURE OF THE WATER IS 20° CELSIUS (ROOM TEMP.)

THE VOLUME OF THE TANK IS 1 000 LITERS. ($1m^3$ = 1000 L - RIGHT?)

THE WEIGHT OF THE WATER (½ TANK) EQUALS ½ OF THE VOLUME, OR 500 LITERS. SINCE 1 LITER = 1 KILOGRAM, 500 L = 500 kg. - OK?

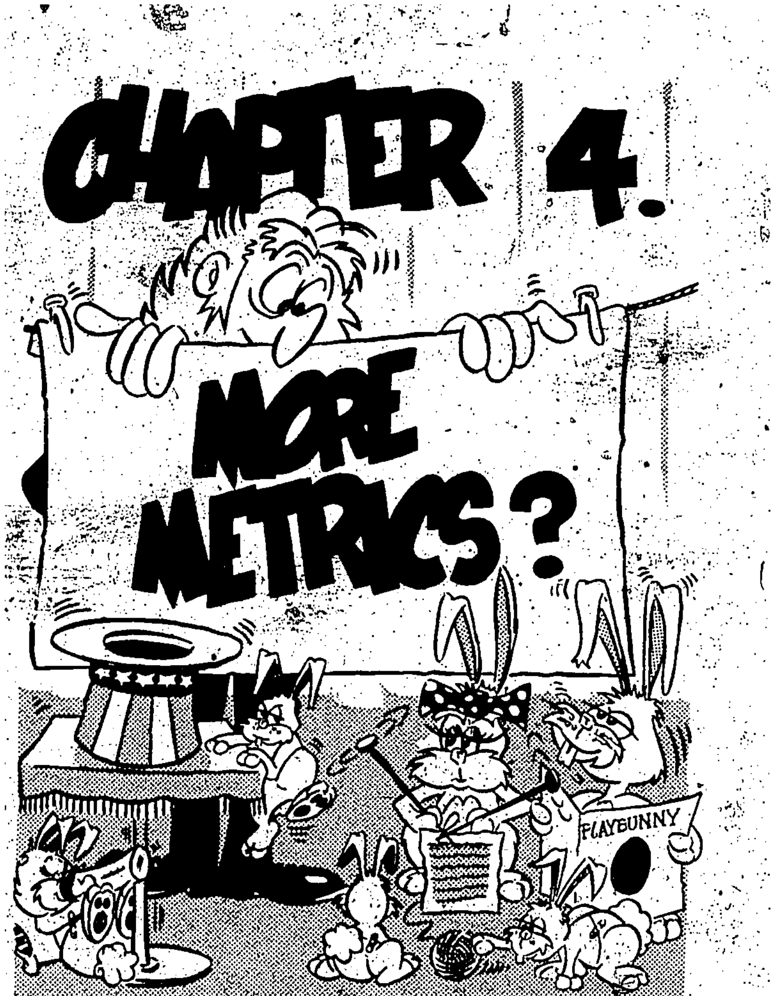
THE AREA OF EACH SURFACE IS 1 SQUARE METER.

THE EDGES OF THE TANK ARE OF EQUAL LENGTH, WHICH IS EXACTLY 1 METER.

THE PERIMETER OF (DISTANCE AROUND) EACH SURFACE IS 4 METERS.

HERE ARE ALL OF THE BASIC METRIC UNITS TOGETHER AS PARTS OF A ONE CUBIC METER FISH TANK, WHICH IS HALF-FULL OF WATER.

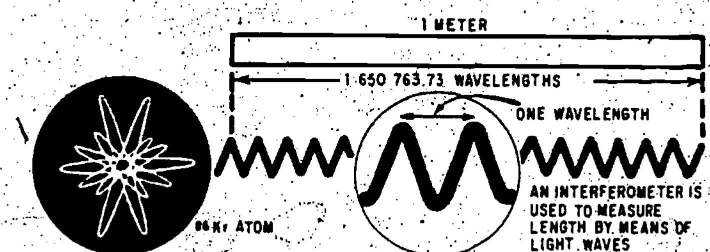
BY TURNING ONE PAGE AT A TIME, YOU BETTER SEE HOW THE UNITS WORK TOGETHER. (PLEASE WATCH YOUR FINGERS, WE HAVE NOT FED THE PIRANHA SINCE LAST JULY.)



SO-WE **LIED** A LITTLE - WOULD YOU BELIEVE **TWO EASY LESSONS?** DO YOU KNOW THAT- ALL **NEWTONS** AREN'T **FIGS** - SOME **MOLES** ARE **ATOMIC** - **KRYPTON** AFFECTS **MORE** THAN JUST **"YOU-KNOW-WHO"** - **HERTZ** HAS **CYCLES** - **KELVIN** HAS A **TEMPERATURE** - YOUR **RADIAN** FROM YOUR **STERADIAN ?** IF **NOT** - INSIDE'S **WATT'S WATT!**

METRIC MEASUREMENTS AND DEFINITIONS

We have given you a basic overview of the metric system. There are other metric measurements used in science and technical work. You may want to know about them, so we have included them in this chapter for reference. They are not important for everyday use.



Meter (m)—length

The meter is the standard unit of length in the metric system and is defined as 1 650 763.73 wavelengths in vacuum of the orange-red light of the spectrum of krypton 86. The metric unit of area is the square meter (m^2). Land is often measured by the hectare (10,000 square meters, or about 2.5 acres). The metric unit of volume is the cubic meter (m^3). Volume of fluid is often measured by the liter (0.001 cubic meters).

Kilogram (kg)-mass

The kilogram is the standard unit of mass. It is the only base unit which is still defined by artifact: the standard kilogram is based on a cylinder of platinum-iridium alloy kept by the International Bureau of Weights and Measures in Paris, France. A duplicate of this cylinder is now stored at the National Bureau of Standards in the United States.

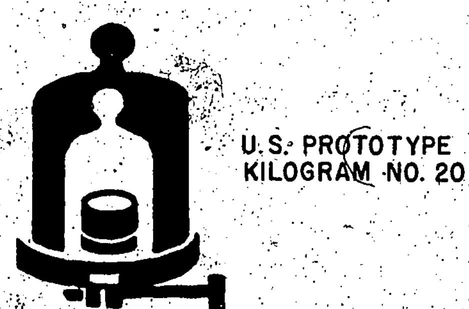
The metric unit of force is the newton. It is defined as the amount of force that, when applied for 1 second, will give a 1-kilogram mass a speed of 1 meter per second.

The metric unit for pressure is the pascal.

The metric unit for work and energy of any kind is the joule, which is defined as 1 newton times 1 meter.

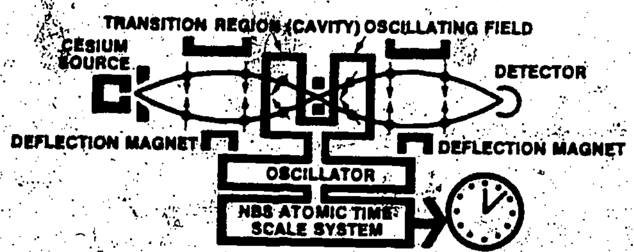
The metric unit for power is the watt, defined as 1 joule per second.

kilogram	kg	
newton	N	$1\ N = 1\ kg.m/s^2$
pascal	Pa	$1\ Pa = 1\ N/m^2$
joule	J	$1\ J = 1\ N.m$
watt	W	$1\ W = 1\ J/s$



A KILOGRAM.

NEWTON (THE SI UNIT OF FORCE).



SCHEMATIC DIAGRAM OF AN ATOMIC BEAM SPECTROMETER OR "CLOCK"

Second (s)—time

The second is the basic unit of time in the metric system and is defined as the duration of 9 192 631 770 cycles of the radiation associated with a specified transition of the cesium 133 atom. It is realized by placing a cesium source at one end of an atomic-beam spectrometer and bombarding the source until its atoms begin to travel at resonance frequency. One set of magnets in the spectrometer causes the atoms to travel in wave form while an oscillator tuned to the resonance frequency permits those atoms traveling at this frequency to pass through that detector which is at the end of the spectrometer. Another set of magnets deflect those atoms not traveling at proper speed. The detector then records the peak of each cycle as it passes. When 9 192 631 770 cycles are recorded, 1 second has passed.

The second was originally defined according to the Earth's rotation. Early in the 20th century it was discovered that the Earth's rate of rotation varies, and a more dependable standard was needed. The present standard for the second was adopted in 1956.

The number of periods or cycles per second is called frequency. The SI unit for frequency is the hertz. One hertz is equal to 1 cycle per second.

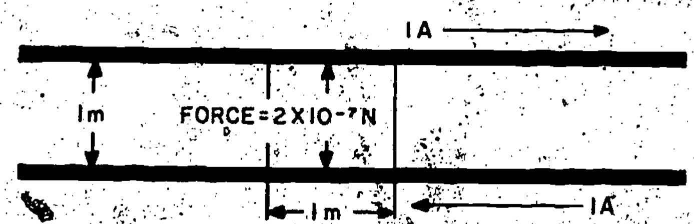
The SI unit for speed is the meter per second.

NOTE: Standard frequencies and correct time are broadcast from WWV, WWVB, and WWVH, and stations of the U. S. Navy. Some shortwave radios receive WWV and WWVH on frequencies of 2.5, 5, 10, 15, and 20 *megahertz*.

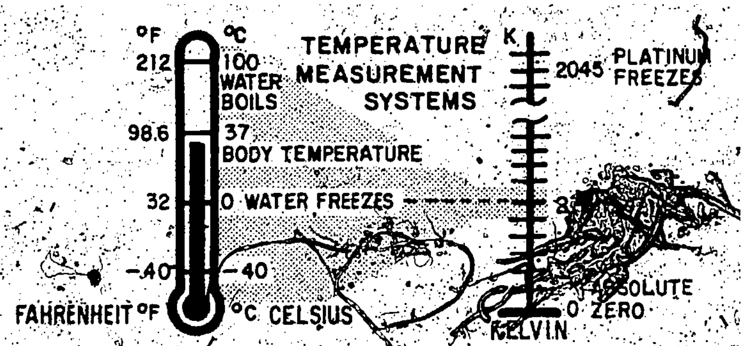
Ampere (A)—electric current

The ampere is the basic unit of electric current in the metric system. It is determined by passing current through two parallel wires separated by a distance of 1 meter, and then measuring the force of attraction between the wires, caused by their magnetic fields. The ampere is defined as that amount of current that will produce a force of exactly 2×10^{-7} newtons between the two wires for each meter of length.

ampere	A	
volt	V	1 V = 1 W/A
ohm	Ω	1 Ω = 1 V/A



A DIAGRAM DEFINITION OF AN AMPERE.



COMPARISON OF TEMPERATURE MEASUREMENT SYSTEMS.

Kelvin (K)—temperature

It is defined as the fraction 1/273.16 of the thermodynamic temperature of the triple point of water. The temperature 0 K is called absolute zero. The Kelvin scale has its origin—i.e., its zero point—at absolute zero. This is the point at which all atomic vibration ceases. The triple point of water (the temperature at which water exists in all three states—vapor, liquid, and solid) is 273.15 kelvins.

On the commonly used Celsius temperature scale, water freezes at about 0°C and boils at about 100°C. The °C is defined as an interval of 1 K, and the Celsius temperature 0°C is defined as 273.15 K.

The degree Fahrenheit is an interval of 5/9°C or 5/9 K. The Fahrenheit scale uses °F as a temperature symbol. The Celsius scale uses °C as its symbol.

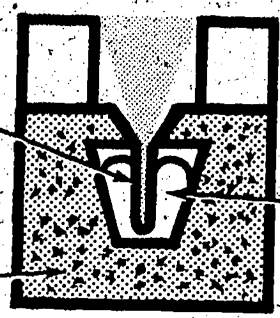
The standard temperature of the triple point is reached by filling an empty glass cylinder (of certain specifications) with pure water. The cell is cooled until a mantle of ice forms around the reentrant well and the temperature at the interface of solid, liquid, and vapor is 273.15 K. Thermometers are then calibrated by being placed inside the triple-point cell. Both the Celsius and Fahrenheit scales are derived from the Kelvin scale.

Mole (mol)—amount of substance

The mole is the standard metric unit for the amount of a particular substance. It is defined as the amount of a substance in a system that contains as many elementary entities as there are atoms in 0.012 kilograms of carbon 12.

When the mole is used the elementary entities must be specified. They may be atoms, molecules, ions, or electrons. They may be other particles or specified groups of such particles. It would not be practical to speak of a mole of apples or a mole of screws because the number of atoms in 0.012 kilograms of carbon 12 is extremely large. Moles are used in chemistry and physics in reference to atoms and molecules.

AMOUNT OF SUBSTANCE IN A SYSTEM COMPARED TO CARBON 12.

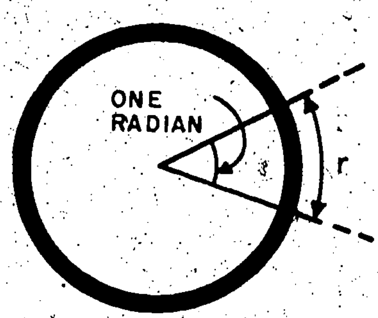


STANDARDS FOR THE CANDELA.

Candela (cd)—luminous intensity

The candela is the basic metric unit of luminous intensity. It is defined as the luminous intensity of 1/600 000 of a square meter of the cone of light emitted by a black body that has been heated to 2 045 kelvins, the freezing point of platinum. A black body is defined as any object that absorbs all the light which shines on it. Because no light is reflected from a black body, the radiant energy is converted to heat, raising the temperature of the object. If, however, the black body is heated, light will radiate from it.

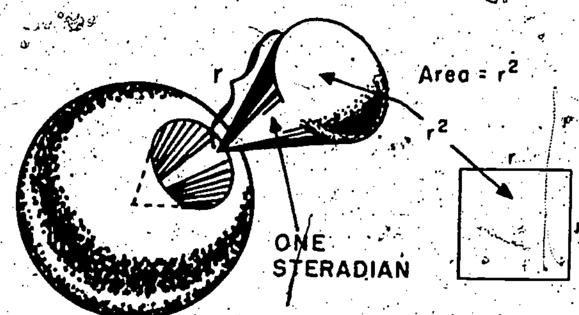
The metric (SI) unit of light flux (amount of light) is the lumen (lm). A source which has an intensity of light of 1 candela in all directions radiates a light flux of 4π lumens. About 1 700 lumens are radiated from a 100-watt light bulb.



A RADIAN.

Radian (rad)—plane angle

The radian is the plane angle with its vertex at the center of a circle that is subtended by an arc equal in length to the radius.



A STERADIAN.

Steradian (sr)—solid angle

The steradian is the solid angle with its vertex at the center of a sphere that is subtended by an area of the spherical surface equal to that of a square with sides equal in length to the radius.

CONVERSION TABLES

This section deals with the techniques used when converting between the inch-pound system and the metric system.

The conversion tables used in this section give approximate conversions between the metric and inch-pound systems of measurement. They are accurate enough for general use.

When a more precise table is used for the conversion, the answers will be different than when the approximate tables are used. This is due to the number of significant digits used for calculations.

METRIC TIPS—a meter is a little longer than a yard (1.1 yards).

—a liter is a little larger than a quart (1.06 quarts).

PSSST...! (TH' OLE GRAY MARE [illegible] AINT WHAT SHE [illegible]TA BE)... HERE'S A TIP STRAIGHT FROM THE HORSE'S MOUTH - PICK "METRICS" TO WIN IN THE 20TH CENTURY! (SEE TOUT SHEETS INSIDE!)

When You Know:	You Can Find:	If You Multiply By:
inches	millimeters	25.4
inches	centimeters	2.54
feet	centimeters	30
feet	meters	0.3
yards	centimeters	90
yards	meters	0.9
miles	kilometers	1.6
miles	meters	1 600
millimeters	inches	0.04
centimeters	inches	0.4
centimeters	feet	0.032 8
meters	feet	3.3
centimeters	yards	0.010 9
meters	yards	1.1
meters	miles	0.000 621
kilometers	miles	0.6
meters	nautical miles	0.000 54
nautical miles	meters	1852

Table 1.—Length Conversion

Problem: Compute the number of kilometers in 86 miles.

Solution: 86 miles X 1.6 kilometers per mile.

$$\begin{array}{r} 86\ \text{mi} \\ \underline{\times\ 1.6\ \text{km/mi}} \\ 51\ 6 \\ \underline{86} \\ 137.6\ \text{km} \end{array}$$

Answer: 137.6 kilometers

METRIC TIP—Here is a British jingle that might help you keep the meter and kilogram straight in your head:

The meter measures three-foot-three
It's bigger than the yard you see
And two-and-a-quarter pounds of jam
Weigh about a kilogram.

Problem: Compute the number of centimeters in 10 1/2 feet.

Solution: 10.5 feet x 30 centimeters per foot

$$\begin{array}{r} 10.5\text{ ft} \\ \underline{\times \quad 30\text{ cm/ft}} \\ 315.0\text{ cm} \end{array}$$

Answer: 315 centimeters

When You Know:	You Can Find:	If You Multiply By:
ounces	grams	28.3
pounds	kilograms	0.45
short tons (2000 lbs)	megagrams (metric tons)	0.9
grams	ounces	0.035 3
kilograms	pounds	2.2
megagrams (metric tons)	short tons (2000 lbs)	1.1

Table 2.—Weight Conversions

Problem: Compute the number of grams in 12 1/4 ounces.

Solution: 12.25 ounces x 28 grams per ounce

$$\begin{array}{r} 12.25\text{ oz} \\ \underline{\times \quad 28\text{ g/oz}} \\ 98\,00 \\ \underline{245\,0} \\ 343.00\text{ g} \end{array}$$

Answer: 343 grams

Problem: Compute the number of pounds in 14.5 kilograms.

Solution: 14.5 kilograms x 2.2 pounds per kilogram

$$\begin{array}{r} 14.5\text{ kg} \\ \underline{\times \quad 2.2\text{ lb/kg}} \\ 2\,90 \\ \underline{29\,0} \\ 31.90\text{ lb} \end{array}$$

Answer: 31.9 pounds

METRIC TIP—a gram is about the weight (mass) of a paper clip; a kilogram equals a little more than two pounds (2.2 pounds).

When You Know:	You Can Find:	If You Multiply By:
teaspoons	milliliters	5
tablespoons	milliliters	15
fluid ounces	milliliters	30
cups	liters	0.24
pints	liters	0.47
quarts	liters	0.95
gallons	liters	3.8
milliliters	teaspoons	0.2
milliliters	tablespoons	0.067
milliliters	fluid ounces	0.034
liters	cups	4.2
liters	pints	2.1
liters	quarts	1.06
liters	gallons	0.26
cubic feet	cubic meters	0.028
cubic yards	cubic meters	0.765
cubic meters	cubic feet	35.3
cubic meters	cubic yards	1.31

Table 3.—Volume Conversion

Problem: Compute the number of liters in 4 1/2 gallons.

Solution: 4.5 gallons x 3.8 liters per gallon

$$\begin{array}{r} 4.5 \text{ gal} \\ \underline{\times\ 3.8 \text{ L/gal}} \\ 3\ 60 \\ \underline{13\ 5} \\ 17.10 \text{ L} \end{array}$$

Answer: 17.1 liters

Problem: Compute the volume in cubic meters of a water tank 10 feet long by 14 1/2 feet wide by 7 feet deep.

Solution: 10 feet x 14.5 feet x 7 feet = 1015 feet
1015 cubic feet x .028 cubic meter per cubic foot

$$\begin{array}{r} 1015 \text{ ft}^3 \\ \underline{\times\ .028 \text{ m}^3/\text{ft}^3} \\ 8\ 120 \\ \underline{20\ 30} \\ 28.420 \text{ m}^3 \end{array}$$

Answer: 28.42 cubic meters

When You Know:	You Can Find:	If You Multiply By:
square inches	square centimeters	6.45
square inches	square meters	0.000 6
square feet	square centimeters	929
square feet	square meters	0.092 9
square yards	square centimeters	8 360
square yards	square meters	0.836
square miles	square kilometers	2.6
square centimeters	square inches	0.155
square meters	square inches	1 550
square centimeters	square feet	0.001
square meters	square feet	10.8
square centimeters	square yards	0.000 12
square meters	square yards	1.2
square kilometers	square miles	0.4

Table 4.—Area Conversion

Problem: Compute the area in square centimeters of a sheet of paper 10 1/2 inches long by 8 inches wide.

Solution: 10.5 inches x 8 inches = 84 square inches
84 square inches x 6.45 square centimeters per square inch.

$$\begin{array}{r} 6.45\ cm^2/in^2 \\ \underline{x\quad 84\ in^2} \\ 25\ 80 \\ \underline{516\ 0} \\ 541.80\ cm^2 \end{array}$$

Answer: 541.8 square centimeters.

Problem: Compute the area covered in square meters by a rug 9 feet wide by 12 feet long.

Solution: 9 feet x 12 feet = 108 square feet
108 square feet x .092 9 square meter per square foot.

$$\begin{array}{r} 108\ ft^2 \\ \underline{x\ .0929\ m^2/ft^2} \\ 972 \\ 216 \\ \underline{9\ 72} \\ 10.0332 \end{array}$$

Answer: 10.033 2 square meters

When You Know:	You Can Find:	If You
degrees Fahrenheit	degrees Celsius	subtract 32 then multiply by 5/9
degrees Celsius	degrees Fahrenheit	multiply by 9/5 then add 32
degrees Celsius	kelvins	add 273.15°

Table 5.—Temperature Conversion

Problem: Compute the degrees Celsius for 70 degrees Fahrenheit.

Solution: $5/9 \times (70° - 32°)$
$5/9 \times (38°) = 190°/9 = 21.1°C$

Answer: 21.1°C

METRIC TIPS—a millimeter (0.001 meter) is about the diameter of a paper clip.

—a centimeter (0.01 meter) is about the width of a paper clip.

—a kilometer (1,000 meters) is a bit longer than a half mile.

GLOSSARY

Ampere. Unit for measuring the flow of electricity. Symbol: A.

Are. Metric surface measure, equal to 100 m². Symbol: a.

Area. Amount of surface, measured in square units.

Atto-. Prefix indicating one-quintillionth of a given unit.

Barrel. Amount contained in a barrel; especially the amount (as 31 gallons of fermented beverage or 42 gallons of petroleum) fixed for a certain commodity. Symbol: bbl.

Boardfoot. Unit of quantity for lumber equal to the volume of a board 12 X 12 X 1 inches. Symbol: fbm.

Bushel. Unit of dry capacity equal to 4 pecks (2150 in^3) or 35.2 liters.

Candela. Unit for measuring the amount of light produced by a light source. Symbol: cd.

Capacity. See volume.

Celsius. Name of the scale for temperature used in conjunction with the metric system. In the Celsius scale, water boils at 100°C and freezes at 0°C, as opposed to 212°F and 32°F, respectively, in the Fahrenheit scale. Symbol: °C.

Centare. Metric surface measure equal to 1 m^2. Symbol: ca.

Centi-. Prefix indicating one-hundredth of a given unit.

Centigram. One-hundredth of a gram. Symbol: cg.

Centiliter. One-hundredth of a liter. Symbol: cL.

Centimeter. One-hundredth of a meter. One centimeter equals 0.394 inch. Symbol: cm.

Chain. Unit of measure equal to 66 feet (20.1 meters). Symbol: ch.

Cubic unit symbols. Examples: mm^3, cm^3, m^3, etc., used to denote volume.

Deca-. (Also deka-) Prefix indicating ten times a given unit.

Decagram. (Also dekagram) Ten grams. Symbol: dag.

Decaliter. (Also dekaliter) Ten liters, roughly equivalent to 2.64 gallons. Symbol: daL.

Decameter. (Also dekameter) Ten meters. One decameter roughly equals 10.9 yards. Symbol: dam.

Deci-. Prefix indicating one-tenth of a given unit.

Decigram. One-tenth of a gram. Symbol: dg.

Deciliter. One-tenth of a liter. Symbol: dL.

Decimeter. Ten centimeters or one-tenth of a meter. Symbol: dm.

Density. The weight of any sample of a substance divided by the volume measure of that sample.

Dram. A unit of avoirdupois weight equal to 27.3 grains or 0.0625 ounce (1.78 grams). Symbol: dr.

Fathom. A unit of length equal to 6 feet (1.83 meters) used for measuring the depth of water. Symbol: fath.

Femto-. A prefix indicating one-quadrillionth of a given unit.

Furlong. Unit of distance (mostly used in horseracing) equal to 220 yards (201 meters). No symbol.

Giga-. Prefix indicating a billion times a given unit.

Gill. Unit of liquid measure equal to .25 pint or about 118 milliliters.

Grain. Unit of weight equal to .0023 avoir ounce (0.065 gram). Symbol: gr.

Gram. Metric unit of weight equal to one-thousandth of a kilogram. Symbol: g .

Hectare. Unit of land measure in the metric system equal to 100 ares or 10,000 square meters and equivalent to 2.471 acres. Symbol: ha.

Hecto-. Prefix indicating one hundred times a given unit.

Hectogram. One hundred grams. Symbol: hg.

Hectoliter. One hundred liters. Symbol: hL.

Hectometer. One hundred meters. Symbol: hm.

Hogshead. U.S. unit of capacity equal to 63 gallons (239 liters). Symbol: hka.

Hundredweight. Unit of weight (avoirdupois) commonly equivalent to 100 lbs (45.4 kilograms) in the United States and 112 lbs (50.8 kilograms) in England. The former is known as the short hundredweight and the latter as the long hundredweight. Symbol: cwt.

Kelvin scale. Temperature scale often used with the metric system and developed by the British physicist Lord Kelvin. The starting, or zero point on the Kelvin scale is absolute zero (-273.15°C, -459.67°F) the lowest theoretical temperature that a gas can reach. On this scale, water freezes at 273.15 K and boils at 373.15 K.

Kilo. Prefix indicating one thousand times a given unit.

Kilogram. Standard unit of mass in the metric system. The kilogram is a cylinder of platinum-iridium alloy kept by the International Bureau of Weights and Measures near Paris. A duplicate kilogram is kept by the National Bureau of Standards in Washington and serves as the mass standard for the United States. One kilogram is equal to approximately 2.2 pounds. Symbol: kg.

Kiloliter. One thousand liters. Symbol: kL.

Kilometer. One thousand meters, equivalent to 3,280 feet or 0.621 mile. Symbol: km.

Link. One of the standardized divisions of a surveyors's chain that is 7.92 inches (201 millimeters) long and serves as a measure of length. No symbol.

Liter. Basic metric unit of liquid measure, equal to the volume of one kilogram of water at 4°C or one cubic decimeter. A liter is equivalent to 1.06 quarts. Symbol: L.

Lumen. Unit for measuring the brightness of light when it reaches the surface of an object. Symbol: lm.

Mass. Amount of material in an object, measured in kilograms.

Mega-. Prefix indicating one million times a given unit.

Meter. Basic unit of length in the metric system. It is defined in terms of the wavelength of orange-red light emitted by a krypton-86 atom (1,650,763.73 such wavelengths to the meter). One meter equals 39.4 inches. Symbol: m.

Metric System. A decimal system of weights and measures, adopted first in France and now in common use worldwide.

Metric Ton. One thousand kilograms, roughly equivalent to 2,200 pounds. Symbol: t.

Micron. The millionth part of a meter. Symbol: μ.

Mile, International Nautical. Unit of distance in sea and air navigation equal to 1.852 kilometers or 6,076 feet.

Mill. Unit of money (but not an actual coin) used primarily in accounting.

Milli-. Prefix indicating one-thousandth of a given unit.

Milligram. One-thousandth of a gram. Symbol: mg.

Milliliter. One-thousandth of a liter. Symbol: ml.

Millimeter. One-tenth of a centimeter or one-thousandth of a meter. Symbol: mm.

Minim. Smallest unit of liquid measure, the sixtieth part of a fluid dram, roughly equivalent to one drop.

Nano-. Prefix indicating one-billionth of a given unit.

Ounce, avoirdupois. Unit of weight equal to 437.5 grains or 0.625 pound avoirdupois (28.3 grams). Symbol: oz. avdp.

Ounce, troy. Unit of weight equal to 480 grains or 0.833 pound troy (31.1 grams). Symbol: oz. tr.

Peck. Dry measure of 8 quarts or the fourth part of a bushel (8.89 liters).

Perimeter. Measure of the distance around a figure.

Pico-. Prefix indicating one-trillionth of a given unit.

Pound, avoirdupois. Unit of weight and mass equal to 7,000 grains (0.454 kilogram) divided into 16 ounces, used for ordinary commercial purposes. Symbol: lb avdp.

Pound, troy. Unit of weight equal to 5,760 grains (0.373 kilogram) divided into 12 ounces troy, used for gold, silver, and other precious metals. Symbol: lb tr.

Radian. Arc of a circle equal in length to the radius of that circle. An angle emanating from the center of a circle that subtends (cuts off) such an arc is said to measure one radian. Measuring angles in radians is preferred with the metric system. Symbol: rad.

Rod. Unit of linear measure, 5.5 yards or 16.5 feet (5.03 meters). Unit of surface measure 30.25 yd^2 (25.3 m^2). No symbol.

Second. The sixtieth part of a minute of a degree. Symbol: ″. (13° 15′ 45″, read as 13 degrees, 15 minutes, 45 seconds).

The sixtieth part of a minute of time. Symbol: s. ($4^h 25^m 12^s$, read as 4 hours, 25 minutes, 12 seconds).

Specific gravity. Ratio of the density of a substance to the density of water at 4°C.

Square unit symbol. Examples: mm^2, cm^2, m^2, etc.

Stere. Cubic meter (1 m^3) equivalent to 35.3 cubic feet or 1.31 cubic yards. Used to measure cordwood. No symbol.

Tera-. Prefix indicating a trillion times a given unit.

Ton, metric. See metric ton.

Volume. Measure in cubic units of the amount of space inside any given container; also the measure of the amount such a container will hold. The latter is known as the capacity of the container and can be given in either units of liquid measure (see liter; milliliter) or in cubic units.

Weight. The force of the Earth's pull on an object. Weight, in the metric system, is measured in grams.

WRITING STYLE GUIDES

The modern form of the metric system is an international language of measurement. As a language, it is governed by rules of spelling, punctuation, and pronunciation. A guide to proper usage follows.

UNITS—Unit names, except at the beginning of a sentence, are lowercase. Note that in the term "degree Celsius," degree is lowercase, but "Celsius" is capitalized. (The "degree centigrade" is obsolete.)

SYMBOLS—Unit symbols are written with lowercase letters; i.e., meter, m. The first letter of a symbol is capitalized, however, when the name of the unit is derived from the name of a person; i.e., newton, N. The exception is the capital letter L used for liter to avoid confusion with the numeral 1.

PREFIXES—Except for tera (T), giga (G), mega (M), newton (N), and kelvin (K), all symbols for numerical prefixes are written with lowercase letters. All prefixes are written in lowercase letters when written in full.

PLURALS—When written in full, the names of units are made plural when appropriate. Fractions (both common and decimal) are always singular.

Symbols for units are the same in singular and plural. (An "s" is never added to a symbol to indicate a plural.)

When writing temperatures, no space should be left between the number designations and the degree.

METRIC TIP—A milliliter (0.001 liter) is about one-fifth of a teaspoon.

sign and between the degree sign and the designation of the scale being used; i.e., 24°F, 20°C.

When writing a symbol after a number to which it refers, a space must be left between the number and the symbol; i.e., 40 mm. (The degree, minute, and second of angle are exceptions.)

PERIODS—A period is not used after a symbol except when the symbol is at the end of a sentence.

THE DECIMAL POINT—A dot placed on the line is used as the decimal point. When writing numbers of a quantity less than one, a zero must be used before the decimal point.

GROUPING OF DIGITS—Digits are separated into groups of three, counting both to the left and to the right from the decimal point. The comma should not be used to separate digits since it is used as a decimal point in many countries. A space is left to avoid confusion; i.e., 1 234 567 0.123 45

In groups of four digits, the space is not recommended; i.e., 1234 0.1234

The space should be used, however, when four-digit numbers are grouped in a column with numbers of five digits or more; i.e.,

```
    14.8
 1 234
+12 345
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METRIC TIPS—To convert Fahrenheit to Celsius temperature: Subtract 32 from the Fahrenheit temperature, multiply the result by 5, and divide that answer by 9.

—Four liters equal 1.06 gallons. Fifteen milliliters equal one tablespoon. Five milliliters equal one teaspoon.

SPACING—When writing symbols or names for units having prefixes, no space is left between letters making up the symbol or the name; i.e., mL, milliliter.

BIBLIOGRAPHY

The five publications listed below are available to Naval activities from:

COMMANDING OFFICER
NAVAL PUBLICATIONS
AND FORMS CENTER
5801 TABOR AVENUE
PHILADELPHIA, PA 19120

AUTOVON 442-3321

*IEEE Standard Letter Symbols for Units of Measurement (SI Units, Customary Inch-Pound Units, and Certain Other Units), ANSI/IEEE Std 260-1978
Ordering identification: IEEE 260-1978

*Metric Editorial Guide, Jan 1978
Ordering identification: ANMC-78-1

*These Industry Standardization Documents received from the Naval Publications and Forms Center include DOD exceptions.

Patternmaker 3 & 2, NAVEDTRA 10578-C, 1973, (Table 8-4.—Metric System and English Conversion). Ordering identification: 0502-LP-052-8910 (Must be requisitioned in MILSTRIP format)

*Standard for Metric Practice (IEEE-268-1976, ANSI Z210.1), 19 Jan 1976
Ordering identification: ASTM-E380-76

NOTE: The above four publications are listed for information purposes only—they are not part of the course.

Use of the Metric System of Measurement, 13 Jun 1978
Ordering identification: SECNAVINST 4120.19

*These Industry Standardization Documents received from the Naval Publications and Forms Center include DOD exceptions.